MINI ALL-PURPOSE SATELLITE CONTROL CENTER (MASCC)

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ABSTRACT

A new generation of Mini All-purpose Satellite Control Centers (MASCC) has been developed by CNES (F). They turn out to be easily adaptable to different kinds of satellites, both Low Earth Orbital or Geostationnary.

The features of this MASCC allow both standard satellite control activities, and checking of passengers experiments hosted on a space platform.
In the different environments in which it may be used, MASCC provides standard broadcasting of telemetry parameters on animated synoptics (curves, bargraphs, alphanumeric displays, ...), which turns out to be a very useful and ergonomic medium for operational teams or satellite specialists.

Special care has been taken during the MASCC development about two points :

- **automation of all routine tasks**, allowing automated operation, and limiting human commitment to system supervision and decision making,
- **software adaptability**.

To reach these two main objectives, the MASCC design provides :

- a simple, robust and flexible hardware architecture, based on powerful distributed workstations,
- a table-driven software architecture, easily adapted to various operational needs. Satellite characteristics are described in a central Data Base. Hence, the processing of telemetry and commands is largely independent from the satellite itself.

In order to validate these capabilities, the MASCC has been customized to several types of satellites and orbital platforms :

- SPOT4 : French new generation of remote sensing satellite,
- TELECOM2 : French geostationary TV and telecommunication satellite,
- MIR : Russian orbital platform.

MASCC development has been completed by the third quarter of 1993.

This paper will provide first a description of the MASCC basic functions, of its hardware and software design. It will then detail the increased automation capability, along with the easy adaptation of the MASCC to new satellites with minimal software modifications.

Key words : MASCC, Satellite Control Center, workstations, adaptation, flexibility, automation.

INTRODUCTION

The Satellite Control Centers are a component of the "satellite(s) ground segment" unit.
Their role is to provide for technical monitoring and control of the satellite and its passengers (through housekeeping telemetry reception, location data and telecommands transmission) and for platform, passenger or payload

management based on planning requests from User Mission Centers.

In addition to the usual criteria for performance, reliability and robustness required from a unit on which the satellite is entirely dependent, the system features the following criteria :

- low development, operating and maintenance costs ;
- very short spaces of time to availability and easy implementation ;
- ease of adaptation to developments concerning either the satellite or the mode of operation used ;
- ergonomic and high quality presentation of data for specialists using sophisticated analysis tools.

The Control Center (MASCC) has been specially developed to meet requirements for rapid adaptation and low operating costs.
The MASCC product was developed directly from work carried out to set up the SPOT 4 Control Center (the French sun-synchronous Earth Observation satellite). This means that it has been able to benefit from development work financed for the SPOT 4 project (high processing capacity, automated operation, ergonomic media for information displays, etc.). The MASCC is equipped with an enhanced range of options and standard features in order to meet requirements for adaptability to different satellites with greater ease.

The MASCC features all the usual Control Center functions and is well adapted for use with non-geostationary satellites such as observation satellites or mini satellites, etc.
It may also be adapted for use with geostationary satellites (with occultation of tasks related to movement and limited satellite visibility).

MASCC FUNCTIONS

Preparation functions

Other than satellite related activities, the MASCC provides for the preparation and generation of the following :

- TeleCommand sets with numerous transmission attributes (burst transmission, operator acknowledgement, time tagging to earliest and latest point, etc.); Command sets stored in an internal library either for real time transmission or for insertion in a "TeleCommand Plan" ;
- synoptic data visualisation with real time display of the various parameters to be viewed in a user-friendly form (curves, bar graphs, active symbols or text, digital display systems, etc.). These synoptic displays are stored as autonomous files.
- parameters (either to be computed in real time from telemetry parameters or previously computed) derived from computation law description through a readily accessible interpreter language.

Preparatory functions to real time activities

The MASCC provides for the preparation of a "TeleCommand Plan" (PDC) to be transmitted to the satellite.
This PDC is generated by inclusion of the TeleCommands stored in an internal library and of TeleCommands from dedicated sub-systems (payload management, orbitography, etc.) within the MASCC computer or distant computers.
The TeleCommands are planned within the PDC in compliance with :

- a forward visibility chronogramme of stations in the case of non-geostationary satellites ;
- operational constraints related to the satellite (masked antenna, etc.) ;
- management constraints related to satellite use (transmission of particular Commands at particular points, class of Command to be used in preference to other classes, etc.).

This "PDC" preparation may be carried out in manual mode under operator control or in automatic mode working from sequencing algorithms.

Real time functions

The MASCC provides all the standard real time functions of a Control Center.

The following list gives the main real time functions provided for :

- interfacing with satellite monitoring stations with automatic testing and station selection (capacity for simultaneous dialogue with two stations) ;
- acquisition and storage of CNES and NASA station location data ;
- acquisition, processing and display of CNES station remote control data ;
- acquisition, processing, display and storage of telemetry data :

  Acquisition may be carried out simultaneously with two stations.

  Processing involves decommutation, implementation of the transfer function, implementation of conditions of significance, application of monitoring functions, processing of the variant part, computation of predicted parameters, computation of prepared parameters via interpreter programme.
- parametered transmission of TeleCommands through transmission of prepared PDC or library stored Commands. This may occur :

  . either in manual mode, Command by Command as the operator implements decisions, with wait time for acknowledgement of each Command ;

  . or in sequenced automatic mode with wait time for acknowledgement of the previous Command ;

  . or in automatic mode but in burst transmission at the maximum rate of the uplink connection, with no wait time.
- display of :

  . synoptics on which all parameters may be shown (telemetry, remote control, computed parameters, etc.) ;

  . alerts (parameter values, operational subsystems, etc.) ;

  . parameters as required with capabilities for display and modification of monitoring thresholds, transfer functions, etc. ;

  . TeleCommand data (Commands under implementation, causes of wait or anomaly, etc.) ;

  . log of all main events occurring during operation.
- distribution of all data received via Internet network to an other MASCC (or several MASCC) dedicated to TX display of a large number of synoptics for monitoring phases such as launch or difficult manoeuvres, etc. ;
- saving of data generated at particular points on a redundant computer ;

Non real time management functions

MASCC features a set of analysis and operational management functions for :

- TeleCommand management after transmission to the satellite by means of a report on each Command transmitted, recycling of non transmitted Commands and generation of a log of Commands describing events involving transmissions to the satellite ;
- Command library management (display, elimination, etc.) ;
- re-run of acquired telemetry with parameterisation of dates, length of time and speed (required rate of transmission : normal, accelerated or step by step) ;
- verification of time-tagging consistency between on-board time and station time-tagging, with re-tagging of acquired telemetry if necessary ;
- storage and compression of acquired telemetry data in a Technical Data Base ;
- extraction and display (curves) of telemetry data over different periods ;
- transmission of acquired data to networks if required (telemetry data, location data, log, etc.).

MASCC DESIGN

Hardware design

Hardware architecture is designed to provide for :

- the type of performance required by Control Center missions ;
- a high level of reliability and availability ;
- ready implementation of further developments ;
- failure management through modular design.

An Ethernet connected work station and X terminals have been opted for.

A satellite is managed at any given moment by one workstation even though several satellite programmes may be operating within one workstation. This option means that the system can be readily modified to cope with developments in satellite families and that redundancies can be managed with ease in high-availability systems.

The workstations selected are :

- RISC architecture HP 9000 series 700 (712, 715 or 735) ;
- SYSTEM V compatible UNIX operating system (HP / UX)

Preference has been given to standard equipment :

- X terminals
- graphic interface : X11, OSF-MOTIF, ILOG library, PV-WAVE ;
- coding : C and C ++ ;
- internal data exchange on TCP/IP,NFS
- External data exchange on X25, FTP.

Hardware options and MASCC function capabilities may lead to different architecture configurations depending on the type of requirement. The diagrams below show different implementation possibilities, depending on mission requirements (Figure-1).
Adaptation to special or temporary needs (improved data distribution, arrival of a new satellite within a family, connection to a dedicated system, etc.) may be carried out without disrupting the existing architecture through the addition of workstations or TX, and if necessary through re-dimensioning of the network.

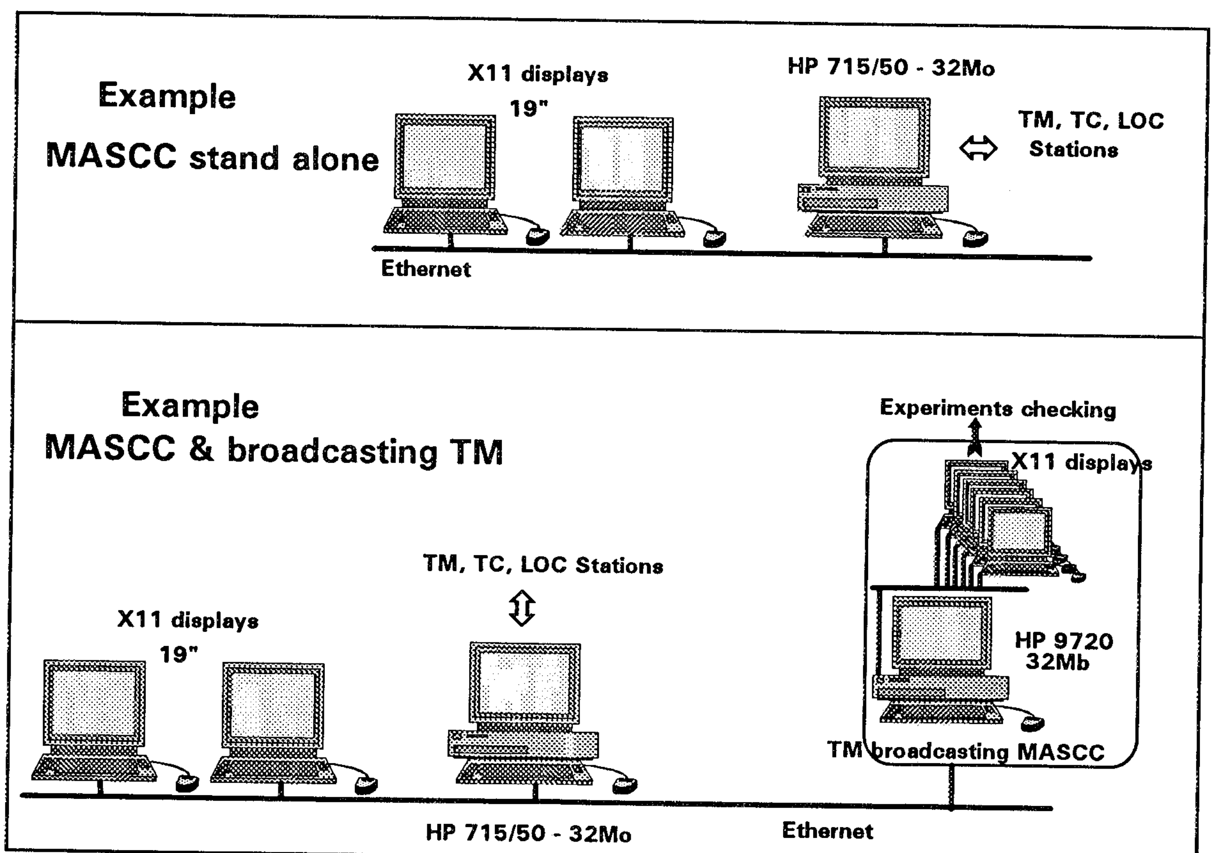
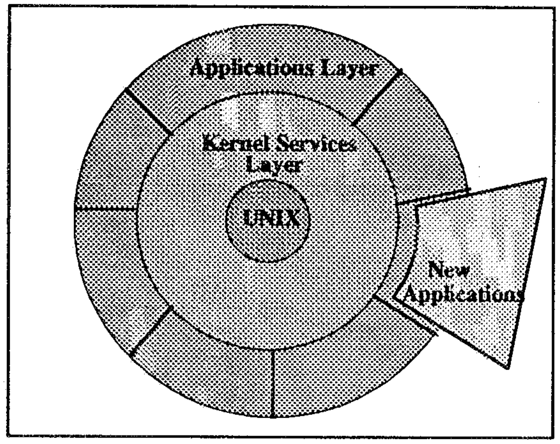


Figure-1: MASCC implementation examples

Software design
Software architecture is made up of two layers above the system layer (HP-UX, OSF-MOTIF) :
- kernel services layer
- applications layer



Kernel Services Layer
This layer forms the basis for the applications layer and enables the applications software and the UNIX system to operate autonomously.
In the case of transfers to new system versions, test operations and maximum cover of test cases will involve this layer (while the applications layer will in general be only slightly modified).
The kernel services layer is made up of :
- Libraries providing for standardisation and access to common services :
  . file management (ASCII for easy editing) ;
  . message management (transfer of messages into files, windows or printers);
  . interprocess communications management (message files, shared memory, semaphore) ;
  . inter-machine communications management
  . time-tag management (time shift capability)
- utilities allowing for simple MASCC management :
  . log use (sort, fusion, etc.) ;
  . hardware and software configuration control ;
  . Digital Data Storage (DDS) ;
  . time synchronisation on different computers ;
- an Agenda which forms the basis of all MASCC automation :
  . simple and ergonomic work programme editing
  . automatic execution of applications defined in a work programme
  . activation and de-activation of applications on a local or distant computer through the network ;
  . re-run capability in cases of incorrect termination of an application.

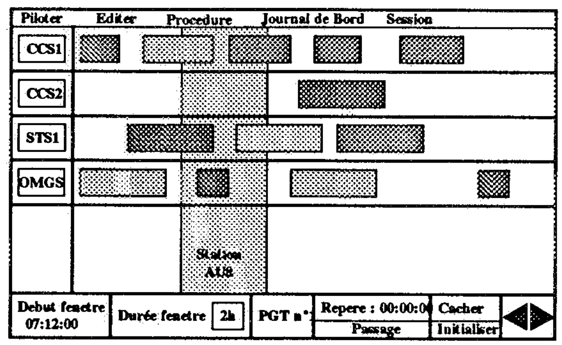


Figure-2: An Agenda work plan scheme

Applications Layer
Strict selection procedures and rules for the design of the MASCC applications layer have been laid down to ensure easy parameterisation and adaptation of the product to different satellites and different modes of operation.

Scissoring by "procedure"
Each operational function is carried out by a software package called a "procedure". These procedures are in overlay above the Kernel Services layer.
A procedure is an autonomous task designed to run without operator intervention and to be executed on one of the workstations. It may be activated automatically by the Agenda (Figure-2) or manually by the operator through an ergonomic man-machine interface.

One of the most important design concepts consists in excluding the automation

constraint from procedure development, as this generally makes software programmes more complex and disrupts the design process. Automation and flexibility in task activation are dealt with by the Agenda.
Moreover, over-riding of overall automation may be activated at will or in the case of any anomaly, however slight.
The other fundamental design concept ensues from the first and provides for the ready modification of "procedure" sequencing, depending on the requirements of the operating team, and if necessary for additional processing (in the form of a "procedure") without disrupting existing tasks and without the need for modifications to existing software for purposes of integration. Adaptation to operating requirements is dynamic in nature.

Building a work plan for one or more days involves defining the required procedures on the Agenda work schedule (Figure-2).
Skeleton work plans are available for the routine operating mode.

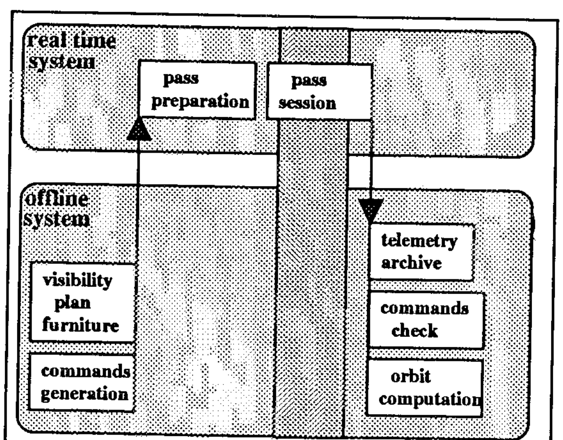


Figure-3: daily routine procedure sequence

Screen Ergonomics
The Man-Machine Interface is implemented on X11 / Motif standards. High resolution screens (19" X11 displays) are available for the implementation of all animated synoptic windows and alphanumerical windows.
Ergonomic specifications (based on the OSF / MOTIF style guide) have been drawn up to ensure that MASCC screens are of uniform design.

MASCC screens are readily adaptable to presentation requirements formulated by operating personnel. Screen features may be modified by means of resource file configuration and parameterisation tables.

Independence from the satellite
Processing carried out by the software is described in tables (System Data Base).
These tables are formatted on the basis of files describing all satellite data (system constraints, parameters, processing, computation laws, transfer functions, monitoring, etc.).
When the processing required to take on a new satellite can be described in these files, the software programmes will take the new satellite into account without the need for modification.
All software modifications observed in different MASCC versions have always been justified by specific satellite behaviour within a specific mode, and have always been kept to a minimum. As a general rule, nominal satellite modes are easily described in the files available.

These files may be supplied by the satellite designer or from data bases containing all the relevant satellite-related data.

Use of ASCII files (SR6-10 format)
Systematic use has been made of ASCII files in SR6-10 format, whether for external or internal interface files (Command, telemetry or satellite description files, etc.).
The kernel services library provides for highly flexible use of these files for the various applications.

The modifications made to files during the MASCC integration and validation phases within a ground segment have been greatly simplified thanks to the use of standard UNIX tools such as "grep", "awk", etc.

Any errors in comprehension at the interface between two units may be by-passed until corrections are made and do not block integration. Data sets and test cases are readily produced (e.g. random telemetry files, etc.), so that system reliability is enhanced by wide test coverage.

Independence between Real Time Processes

Independence between non real time tasks is assessed through the concept of "procedures" and the use of Agenda. The Agenda synchronises procedures which involve data exchange, generally through files.

On the other hand, the tasks running simultaneously in real time (telemetry processing, command transmission, window or synoptic displays, acquisition of network blocks, etc...) are activated in a unique procedure and exchange data through high rate message queues.
The MASCC has implemented a protocol providing for independence between the data-generating tasks and data-consuming tasks : the producer / consumer protocol.

A task providing data (Network interface, telemetry, ...) doesn't know tasks using it (synoptic display, Telecommand, ...).

For instance, a synoptic displays Telemetry parameters and the receiving station. These data are processed by two different functions : "Telemetry" and "Network Interface". The synoptic needs them for display. Hence, the "synoptic" function subscribes to these parameters through the producer/consumer protocol, without knowing who is producing them. Once initialized, "Telemetry" and "Network Interface" functions know through the protocol tables, which parameters to provide, at which frequency and to which receivers.

This mechanism allows a large genericity between Real time tasks and supports easy modifications of managed data and addition of new consuming tasks, delocated or not.

ADAPTABILITY CAPABILITIES

In order to validate MASCC adaptability, a number of goals were set :

- adapt to a Low Orbit Satellite;
- adapt to a Geostationnary Satellite;
- adapt to On Board Experiments monitoring;
- carry out the corresponding modifications in the shortest delay;
- display the results on an unique platform.

The easiest adaptation consisted in adjusting MASCC to the French observation satellite SPOT4, MASCC being directly issued of SPOT4 Control Center design.

The Geostationnary Satellite used for this test was TELECOM2, French satellite for telecommunication and television broadcasting.
The adaptation, here, consisted in describing Telemetry in the System Data Base. Some particularities of this telemetry, such as DWELL data, required software modifications. Details of parts modified and corresponding efforts are provided in the following table.

Modification details table

Task	Technical description	Modification size	Effort
Telemetries differences analysis and choice of a solution			4 days
"System Data Base" adaptation	specific tool (awk)	entirely developped	4 days

Task	Technical description	Modification size	Effort
Adaptation for the archiving telemetry format	specific tool (run task)	entirely developped	4 days
Adaptation of TC2 synoptics	specific tool (awk)	entirely developped	4 days
TM treatments modification	taking into account : - new format (21 frames) - dwell characteristics - bits inversion	7 sets modified (1000 lines) 4 interface files (80 lines)	6 days
Man Machine Interface telemetry re-run modification	new look for the MMI		4 days
Telemetry re-run control	taking into account : - new format (21 frames) - new frequency (1,2s)	2 sets modified (20 lines)	2 days
General information display	dwell informations display new format display	2 sets modified and one data file (20 lines)	1 day
Synoptics files creation and modification	checking TM modification		3 days
Integration, validation			5 days
Installation, acceptance			4 days

Modifications have been performed by two skilled MASCC designers.

The last adaptation dealt with the Telemetry provided by the Russian platform MIR, for an off-line analysis of parameters (On board Experiments, vehicles rendezvous data, ...). Telemetry is available on a diskette for tests in France or on an Ethernet network within the TSOUP facilities. Both description of this Telemetry in the System Data Base and efforts in reordering events were required. This adaptation, which has been performed during two months, is now running in TSOUP facilities.

All these adaptations were performed without modifying the central structure of MASCC. Man Machine Interfaces were configurated to manage display requirements and available supports.

CONCLUSIONS

MASCC development was completed in late 1993.

The system is now operating in the main CNES control rooms when launches are carried out, to distribute telemetry data to the "spacecraft" specialists.
Today, the MASCC is being considered as a replacement for the SPOT 2 and SPOT 3 Control Centers now operating, involving minimal cost and with up-to-date hardware ensuring low cost maintenance.
The MASCC is included within the Control Center selection list being reviewed by CNES for its mini-satellite programme.

MASCC enhancements are planned to coincide with the implementation of the new SPOT 5 generation of Earth Observation satellites and others.

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Author Index

MM - Mission Management, OP - Operations, DM - Data Management, SE - Systems Engineering, SD - Systems Development, * *Presented in Poster Session*

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Under the theme of "Opportunities in Ground Data Systems for High Efficiency Operations of Space Missions," the SpaceOps '94 symposium included presentations of more than 150 technical papers spanning five topic areas: Mission Management, Operations, Data Management, System Development, and Systems Engineering.

As stated in the executive summary of the symposium proceedings, the papers "focus on improvements in the efficiency, effectiveness, productivity, and quality of data acquisition, ground systems, and mission operations. New technology, techniques, methods, and human systems are discussed. Accomplishments are also reported in the application of information systems to improve data retrieval, reporting, and archiving; the management of human factors; the use of telescience and teleoperations; and the design and implementation of logistics support for mission operations."

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